Nanometrologies Needed for the Monolithic Fabrication of Nanoscale Electronic Devices and Circuits

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Abstract

Manufacturing semiconductor devices at the nanoscale will result in many new measurement challenges. CMOS nanoscale devices and circuits are currently approaching gigascale levels of integration and could be heading towards terascale densities if new non-CMOS nanoscale device concepts that integrate with CMOS can be demonstrated. However, current reports on nanoscale electronic and spintronic devices have not yet demonstrated performance levels approaching those of scaled CMOS. Also, it is widely anticipated that nanoscale devices will suffer from higher failure rates due to process variability, operating temperature and voltage variations, and the effects of very high electric fields intrinsic to nanoscale operation. Process variations arise from the fact that patterning is performed by optical lithography where the (illuminating?)imaging photons are larger than the features they are imaging. Ultimately nanofabrication must be performed by "bottoms-up" directed self-assembly methods; however the registration and alignment needed from one layer to the next are still serious sources of variability. Line edge roughness is also a serious problem as plasma etching becomes sensitive to variations such as molecule size and alignment in polymeric transfer materials. Voltage variations arise from the very small cross sections of nanoscale interconnects and the potentially high contact resistances.

Success in nanomanufacturing of these devices will rely on new nanometrologies needed to measure basic materials properties including their sensitivities to temperature and field variations, to control the nanofabrication processes, and to explore failure mechanisms. The nanometrology methods needed include both probe measurement methods (electron, proximal, and photon) and optical measurement methods (reflectometry, polarizing reflectometry, spectroscopic ellipsometry, and energy-level spectroscopies). These imaging and measurement methods must be performed in real time to allow simultaneous measurement of properties and imaging of features at the nanoscale. The nanometrologies must be supported by physical models that allow the deconvolution of probe-sample interactions as well as to interpret sub-surface interface behaviors.

Several nanometrology research projects within ONAMI address these challenges including basic measurements of plasmons and electrical transport, heterostructure nanowire behavior, SIMS/AFM nanotomography, shear-force AFM, dual mode ellipsometer/AFM imaging, and photoemission at high spatial resolution.